UNIVERSITI PUTRA MALAYSIA

PHYSICAL AND THERMAL CHARACTERIZATION OF GLASS CERAMICS PREPARED FROM CULLET AND COAL BOTTOM ASH

MOHD ZUL HILMI BIN MAYZAN

PHYSICAL AND THERMAL CHARACTERIZATION OF GLASS CERAMICS PREPARED FROM CULLET AND COAL BOTTOM ASH

By

MOHD ZUL HILMI BIN MAYZAN

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Master of Science

September 2010

DEDICATION

TO MY FAMILY

Mayzan bin Mansor

Norhana binti Nayan

Mohd Zulfadhli bin Mayzan

And my loving memories to

Mohamad Zul Fahmi bin Mayzan

Thank you for the inspiration and encouragement in everything I do

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Master of Science

PHYSICAL AND THERMAL CHARACTERIZATION OF GLASS CERAMICS PREPARED FROM CULLET AND COAL BOTTOM ASH

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September 2010

Chairman: Associate Professor Zaidan Abdul Wahab, PhD

Faculty: Science

This thesis describes the physical and thermal characterization of glass ceramics prepared from mixtures of soda lime cullet glass and coal bottom ash. The aim of this research is to develop and optimize the phase and structural properties, microstructure, density, linear shrinkage and Vickers micro hardness as well as to determine the thermal diffusivity behavior of glass ceramics. Three batch compositions of glass ceramics were obtained by mixing 50-90 weight percent of soda lime cullet glass with 10-50 weight percent of coal bottom ash, undergone the vitrification method by melting the compositions at 1450˚C for 3 hours and heat treating the compacted powdered glasses between 700 and 1000˚C for 2 hours at 100˚C intervals. The vitrification method offered a solution for the disposal of soda lime cullet glass and coal bottom ash as well as to minimize their hazardous effects to the environment.

The resulting samples were characterized by using several characterization techniques involving X-ray fluorescence spectroscopy, differential thermal analysis, X-ray diffraction, scanning electron microscope with energy dispersive X-ray, optical microscope, density, linear shrinkage, Vickers micro hardness and thermal diffusivity determination by using flash method. The differential thermal analysis on all powdered glasses revealed that the crystallization temperature occur above 700˚C. The crystalline phases were identified as wollastonite [$CaSiO_3$], augite, aluminian [$Ca(Mg,Fe,Al)(Si,Al)_2O_6$] and albite, disordered [$NaAlSi_3O_8$]. Wollastonite crystals had whisker-type with acicular grains and needle-like morphologies, augite, aluminian crystals had feather-like and small oval-like morphologies while samples that have crystalline phases of augite, aluminian and albite, disordered had scratch-like morphologies. The measured density, linear shrinkage, Vickers micro hardness and thermal diffusivity for all heat treated samples were in range of 2.70 to 2.76 g/cm^3, 0.83 to 14.04 %, 496.2 to 747.9 kg/mm^2 and 0.133 to 0.766 mm^2/s respectively. Generally, the glass content in heat treated samples is responsible in reducing the density, Vickers micro hardness and thermal diffusivity values. According to the findings in all characterization techniques, the most promising heat treated samples at each batch composition were suitable for industrial use, especially in the manufacturing of tiles.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Master Sains

PENCIRIAN FIZIKAL DAN TERMA SERAMIK KACA DISEDIAKAN DARIPADA KEPINGAN KACA DAN ABU BAWAH ARANG BATU

Oleh

MOHD ZUL HILMI BIN MAYZAN

September 2010

Pengerusi: Profesor Madya Zaidan Abdul Wahab, PhD

Fakulti: Sains

Tesis ini memperihalkan pencirian fizikal dan terma seramik kaca disediakan daripada pelbagai campuran kepingan kaca kapur soda dan abu bawah arang batu. Tujuan penyelidikan ini adalah untuk menghasilkan dan mengoptimumkan sifat-sifat fasa dan stuktur, mikrostuktur, ketumpatan, pengecutan linear dan kekerasan mikro Vickers serta menentukan kelakuan keresapan terma seramik kaca. Tiga kumpulan komposisi seramik kaca diperolehi daripada campuran 50-90 peratus berat kepingan kaca kapur soda dengan 10-50 peratus berat abu bawah arang batu, menjalani kaedah pengkacaan dengan meleburkan komposisi-komposisi tersebut pada 1450˚C selama 3 jam dan perawatan haba serbuk kaca yang dipadatkan pada julat suhu diantara 700 dan 1000˚C selama 2 jam pada selang 100˚C. Kaedah pengkacaan menawarkan penyelesaian untuk melupuskan kepingan kaca kapur soda dan abu bawah arang batu serta meminimumkan kesan yang berbahaya terhadap alam sekitar.

Sampel-sampel yang diperolehi dicirikan dengan mengunakan beberapa teknik pencirian membabitkan spektroskopi pendarflour sinar-X, analisis pembezaaan terma, pembelauan sinar-X, mikroskop pengimbas elektron dengan sebaran tenaga sinar-X, mikroskop optikal, ketumpatan, pengecutan linear, kekerasan mikro Vickers dan keresapan terma yang ditentukan mengunakan kaedah lampu kilat. Analisis pembezaan terma pada semua serbuk kaca menjelaskan bahawa suhu penghabluran berlaku selepas 700˚C. Fasa-fasa hablur yang dikenal pasti adalah wollastonite [$CaSiO_3$], augite, aluminian [$Ca(Mg,Fe,Al)(Si,Al)_2O_6$] dan albite, celaru [$NaAlSi_3O_8$]. Hablur wollastonite mempunyai bentuk seperti misai dengan butir-butir menjarum dan bentuk jejarum, hablur augite, aluminian mempunyai bentuk seperti bulu pelepah dan bujur kecil manakala sampel-sampel yang mempunyai fasa hablur augite, aluminian dan albite, celaru mempunyai bentuk seperti kesan calar. Pengukuran ketumpatan, pengecutan linear, kekerasan mikro Vickers dan keresapan terma untuk semua sampel yang telah melalui rawatan haba adalah masing-masing dalam lingkungan 2.70 hingga 2.76 g/cm^3, 0.83 hingga 14.04 %, 496.2 hingga 747.9 kg/mm² dan 0.133 hingga 0.766 mm^2/s. Pada amnya, kandungan kaca pada sampel-sampel yang telah menjalani rawatan haba bertanggungjawab merendahkan nilai ketumpatan, kekerasan mikro Vickers dan keresapan haba. Menurut penemuan pada semua teknik-teknik pencirian, sampel-sampel yang terbaik selepas menjalani rawatan haba pada setiap kumpulan komposisi adalah sesuai untuk kegunaan industri, terutamanya dalam pembuatan jubin.

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I certify that a Thesis Examination Committee has met on 20th September 2010 to conduct the final examination of Mohd Zul Hilmi bin Mayzan on his thesis entitled "Physical and Thermal Characterization of Glass Ceramics Prepared from Cullet and Coal Bottom Ash" in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The Committee recommends that the student be awarded the degree of Master of Science.

Members of the Thesis Examination Committee were as follows:

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This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Master of Science. The members of the Supervisory Committee were as follows:

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Date:

DECLARATION

I declare that the thesis is my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously, and is not concurrently, submitted for any other degree at Universiti Putra Malaysia or at any other institution.

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MOHD ZUL HILMI BIN MAYZAN

Date: 20 September 2010

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